37. Pacific Salmon: An Attempt to evolve something of their History from an Examination of their Scales.

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(Text-figures 95–118.)

Salmonidæ: Structure, Development, Ethology.

The above title indicates what is perhaps a somewhat bold venture on the part of one who lives on the east side of the Atlantic, and who has only once seen a freshly killed Pacific salmon during a short visit to Vancouver in 1893. The reasons for my undertaking it are that, so far as I have been able to ascertain, the study of salmon scales has not yet made much progress in America, that undoubtedly much may be discovered from them, and that even such inadequate observations as I have been able to make may afford most valuable hints to others better able to procure materials for the study of the habits of the so-called salmon of the Pacific. I say *so-called*, because with one exception, *Salmo gairdneri*, the Steelhead Trout, the Pacific salmon do not belong to the same division of the genus *Salmo* as the salmon of the Atlantic Ocean. Excepting the Steelhead, they belong to the subgenus *Oncorhynchus*, while our salmon and trout belong to the subgenus *Salmo*.

I shall have to notice five species of *Oncorhynchus* which breed in the rivers and streams of Western North America. They are *O. quinnat*, or *O. tschawytscha*, the Quinnat, King, Tyee, or Spring Salmon ; *O. nerka*, generally known as the Sockeye, from the sunken appearance of the eyes, and also called the Blueback and the Red Salmon ; *O. kisutch*, the Cohoe, Silver, White, or Fall Salmon ; *O. gorbuscha*, the Humpback, so called from a peculiar hump which appears on the backs of the males at spawning time; and *O. keta*, the Dog or Chum Salmon. A sixth species, *O. masu*, is found on the Siberian coast and in Japan, but I shall not deal with it here, as I intend to confine my remarks to the salmon of the Pacific coast of North America. It is there that full knowledge of the habits of the Pacific salmon is of the greatest importance on account of the magnitude of the canning industry, to which every one of the native species now contributes its quota.

When the canning industry was first started in the West, the Quinnat only was cared for, but soon the Sockeye was recognized as a fish of much greater importance. The value of the remaining species has only recently been appreciated.

It is generally believed that none of the fish of the genus *Oncorhynchus* that go to the rivers ever return and that all die after

* Communicated by the Secretary.

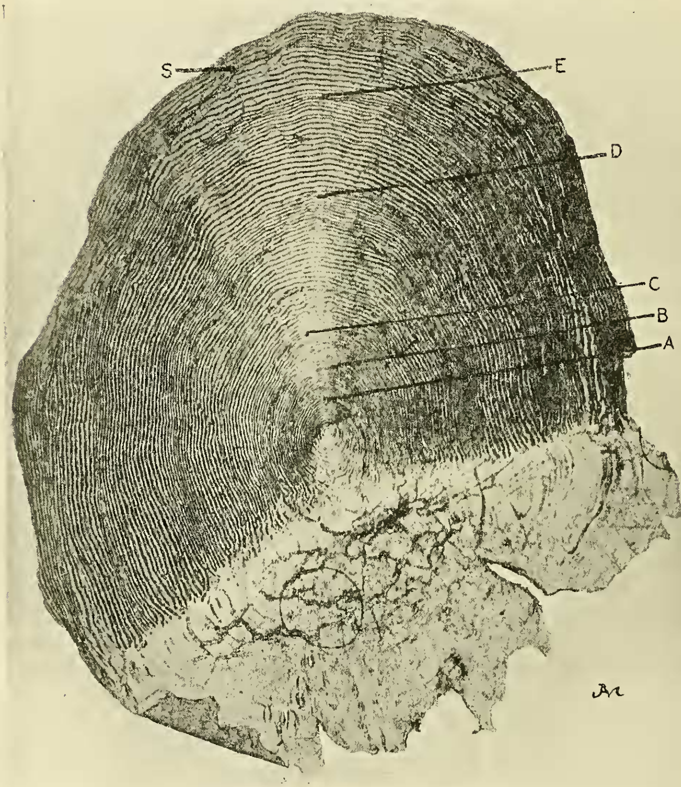
spawning. But although the upper tributaries of the Fraser River are almost unapproachable for some time after the spawning season, on account of the numbers of dead and putrefying fish which they contain, I do not think it is absolutely proved that all the fish do die after spawning. Later on I shall produce something approaching a proof that they do not. Most of them undoubtedly do die then. Many of our Atlantic salmon are so exhausted after spawning that they promptly die. Much more so must that be the case with these Pacific salmon, which ascend the rivers not for a few tens of miles as our fish do, but for some hundreds, or even for many hundreds of miles. The probability certainly is that when they go very far from the sea, none of them return. But they do not all ascend to extreme distances; and I can see no reason why some of those which have not had far to go, or great difficulties to surmount on the journey, should not have sufficient strength to recover and to spawn again. I well remember the manager of one of the largest canneries on the Fraser saying to me that the idea that all the fish died was based on the statements of Indians only; that no one else knew anything about it (I speak of twenty years ago), and that millions of kelts might come down the middle of the Fraser with the stream, and not a soul be any the wiser. To my mind the fact that no kelts are ever seen does not prove their absence. No netting is going on when the kelts would come down, so, as no Pacific salmon can jump, and as no Pacific salmon has ever been known to take a bait in fresh water, it is most improbable that they would be seen.

It was in the hope that some definite evidence might be forthcoming upon this point that I first took up the study of the scales of Pacific salmon. One certain spawning mark would disprove the idea that every fish dies. But even on our Atlantic Coast the percentage of fish that are recaptured after having spawned is very small; and on the Pacific Coast the percentage must, for the reasons mentioned, be much smaller. Supposing it to be as high as one in a hundred, which it probably is not, it might be necessary to examine the scales of some thousands of fish before that one happened to be among them. I have not been able to examine the scales of more than a few dozens, but I think that I have been so lucky as to find a spawning mark on the scales of a large Quinnat. One of its scales is shown in text-fig. 95 (p. 574), and I believe that the mark about a quarter of an inch from the edge of the photograph is a spawning mark. I shall have more to say about it later on when I come to deal with the Quinnat salmon in detail.

As against the general belief that Pacific salmon never survive spawning, I have heard the argument that the largest Quinnats, which weigh from 50 to 100 lbs., must be very old fish and that they must almost certainly have spawned. In text-fig. 96 (p. 575) is shown the scale of one which weighed 62½ lbs. It has certainly not spawned, and it is also certainly not old. It appears to be only in its fifth year but to have grown very regularly and fast both in summer and winter throughout its life.

As I have to reason largely from analogy, I must now digress for a time from my immediate subject to say a little about what has been discovered from the scales of our salmon, *Salmo salar*, which is also the salmon of the east side of the American continent.

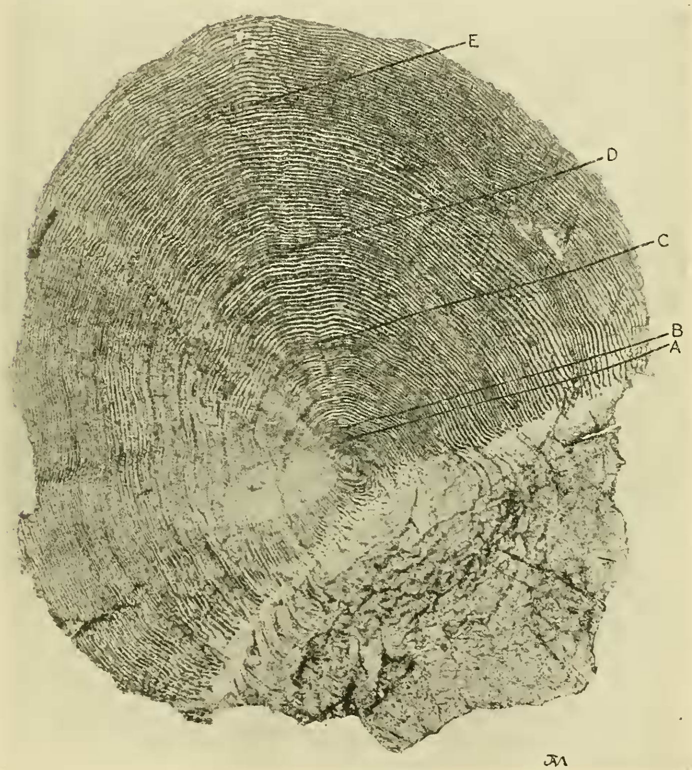
Text-fig. 95.



Scale of a Quinnat (*Oncorhynchus tschawytscha*) $33\frac{1}{4}$ lbs. Length $41\frac{1}{2}$ ins.; girth $25\frac{1}{2}$ ins. Captured at New Westminster, B.C., in 1912. Supposed spawning mark shown at *S*.

It appears to have occurred to Leuwenhoeck so long ago as the year 1696, and to Réaumur in 1716, that the concentric lines which are to be found upon the outer surface of the scales of most fishes are formed with some relation to the age of the scale, and therefore must give an indication of the age of the fish to which the scale belongs. But no very close or reliable investigations as to how the ages of salmon might be read from their scales were made until Mr. H. W. Johnston took up the study a few years ago. Although I am not actually quoting from anything he has written, I think his authority for everything I am going to say, unless I may quote someone else, will be found in one or other of his contributions to the Reports of the Scottish Fishery Board. (See Parts II. of the Reports for 1904, 1906, and 1907.)

Text-fig. 96.



Scale of a Quinnat (*O. tschawytscha*) $62\frac{1}{2}$ lbs., ♂. Length $50\frac{3}{4}$ ins.; girth 31 ins. Captured at New Westminster, B.C., in 1912.

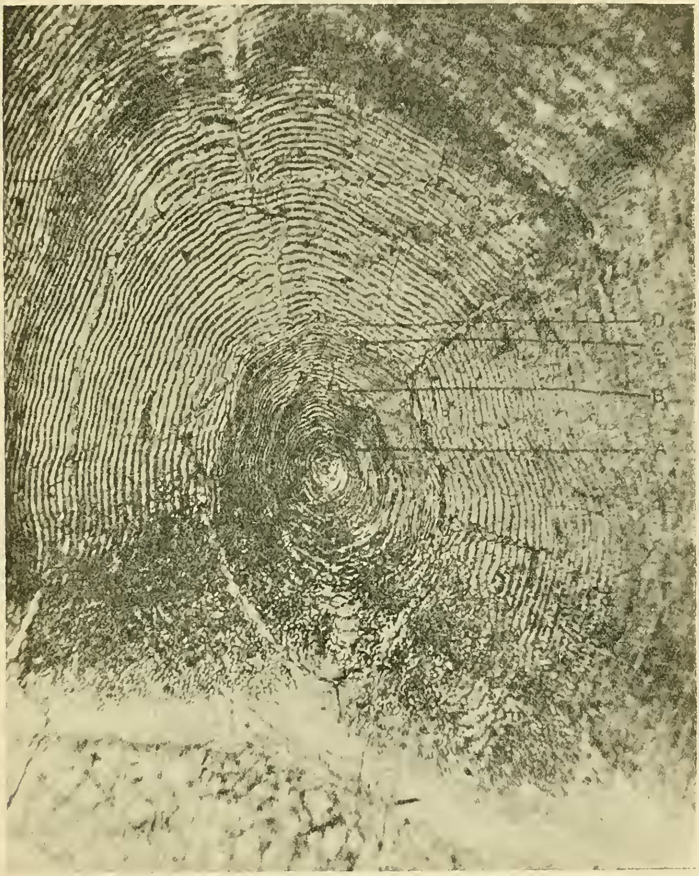
A salmon scale is divided into two areas, one, the anterior and larger part, being enclosed in a pocket in the skin, to which it is loosely attached; the other, the posterior area, being the only part of the scale which we see while it is still attached to the fish. The anterior part is covered by a mass of concentric lines or ridges, from the relative positions of which much may be learned. The posterior part is almost without lines. This formation is common to the scales of all members of the genera *Salmo* and *Oncorhynchus*. The whole scale is covered by a membrane and grows with the fish. When the fish—and with the fish, the scales—grows slowly the concentric lines, which seem to be produced at a fairly uniform rate as to number, are situated closely together; when they grow quickly the lines are placed further apart. When the fish does not grow at all, the scales also cease to grow, and no lines are added to their surfaces. The scales first appear upon young salmon as minute bony plates under the skin. They may first be noticed when the fish is about three months old, and about $\frac{3}{4}$ inch in length (Vogt, 'Embryologie des Salmones,' 1842, Klaatsch 1890, and Dahl, 'Age and Growth of Salmon and Trout in Norway,' 1912). When about four months old and $1\frac{1}{4}$ inches long the little fish may have from 2 to 5 rings round their scales; and when about eight months old, that is just before the winter comes on, there may be, roughly speaking, from 8 to 20 lines already visible on each of their scales. Within small limits the number of lines varies in different scales even from the same fish. We know that the yearlings when kept in ponds feed well and grow rapidly during the summer months, and that as winter approaches they take less nourishment, finally at times fasting completely for three or four days on end. We also know that their growth progresses in proportion. This mode of life is clearly depicted on their scales. Surrounding the nucleus, the lines formed in summer are at some small distance from each other, and each line can usually be traced right round the scale. The lines formed in winter are much closer together and are usually more numerous on the anterior portion of the scale.

When the growth of the next year begins in the spring, the lines first formed are again wider apart and generally continuous all round the scale, and, later on, the winter formation of the first year is repeated. Thus there is formed an area of well-spaced lines followed by a band composed of lines very close together. This band is usually most noticeable in front, and is followed by another area of open lines and a second band which is probably not quite so well defined as the first. The accompanying photograph (text-fig. 97) of the central part of the scale of a Steelhead Trout (*S. gairdneri*) well illustrates the formation. The line A points to the completion of the first winter band, B of the second winter band, C of the third, and the end of the line D shows the point in the next year when the smolt left the river and commenced to grow rapidly in the sea.

In the sea growth proceeds as before, but at a much increased rate, and the difference between fast summer and slower winter growth continues to be apparent on the scales.

Fish that are born, and spend all their lives in the sea, show annual winter bands like the others ; but, except for these bands, the spacing between the lines shows no sudden increase due to any abrupt change in the mode of life. Compare text-fig. 98, the photograph of a scale of a large haddock, with the other photographs illustrating this paper, and the difference in the

Text-fig. 97.



Centre of scale of a Steelhead Trout (*S. gairdneri*) from the Fraser River, much magnified, showing three winter bands before migration to the sea. (For references see the text, p. 576.)

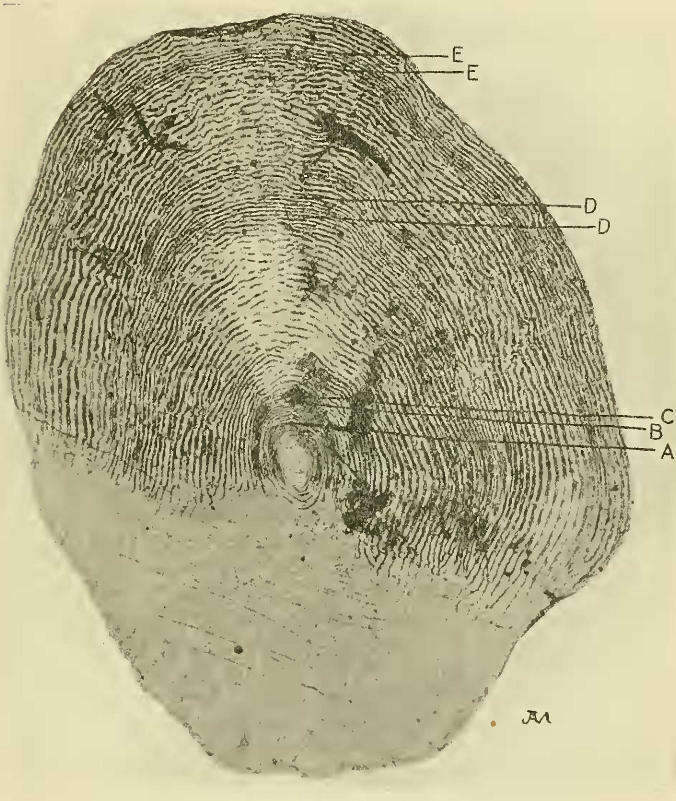
centres will be at once apparent. I wish to emphasize this difference because the Pacific salmon scales, if we except those of *O. keta*, the Dog Salmon, show a sudden change of growth just as do those of the true salmon ; and this, to my mind, at once disposes of the idea that these fish go down to the sea almost as soon as they are hatched and commence feeding only when they get there.

Text-fig. 98.

Scale of a large Haddock (*Gadus æglefinus*). × about 40.

Mr. Johnston kindly gave me some of the scales taken from salmon which had been marked as smolts in the estuary of the Tay in the early summer of 1905. The smolts were then on their way to the sea, and the marks were still attached to the fish when subsequently recaptured as salmon. Thus the exact times spent by them in the sea were known, and it was found, as had been expected, that the summer and winter bands on the scales agreed with the known times. Text-fig. 99 is a scale from one of these fish which was captured in the Tay nets on May 7th, 1907. It had been marked as a smolt when the scale had grown to the point C, and when the fish was just over two years old. The winter band formed in the winter 1905–6 is apparent between the points marked D, and the band formed in the winter

Text-fig. 99.



Scale of $12\frac{1}{4}$ lb. salmon (*Salmo salar*) caught in the Tay nets on May 7th, 1907. Previously marked as a smolt in May 1905. (For references see the text, *supra*.)

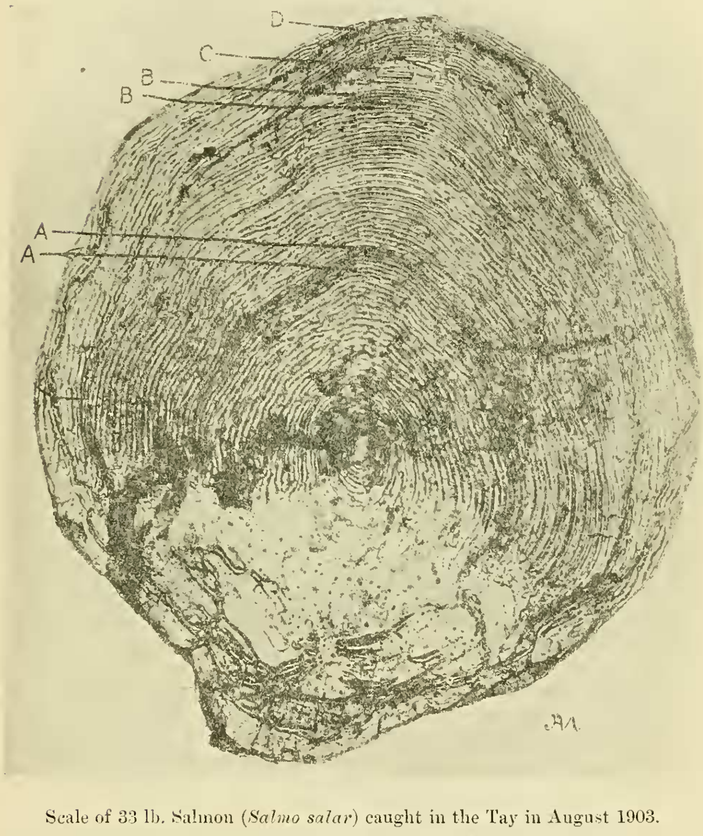
1906–7 between the points E. Outside the last band is seen the quick growth made in the summer of 1907 previous to May 7th, when the fish was netted. Summer growth is the term used in distinction to winter growth. It does not mean growth taking place only in June, July, and August, our summer months. It evidently starts and finishes at varying times, the probable limits being about the middle of March and the middle or end of September.

The foregoing remarks may suffice to explain the regular markings on salmon scales, and how they show the age and time of migration of the salmon. Scales, however, may show much more.

Mr. Johnston noticed that the scales of the older fish sometimes seem to have stopped growing, and become jagged and broken at the edges, and then to have gone on growing again. When this has happened the lines of the new growth do not exactly follow the contours of the lines of the old growth, and thus a clear mark is formed round the anterior portion of the scale, often also apparent as a thickening round the posterior, the unlined, portion. Further, it was noticed that when such a mark occurred the number of lines between the winter bands on each side of it was frequently far from normal. The normal number differs somewhat in different fish, and also within certain limits on scales from different parts of the same fish; but nevertheless it is fairly constant, and any wide departure from the usual state of things required explanation. A reason for the mark suggested itself to Mr. Johnston from the known fact that salmon, whether or not they take food in fresh water, do not take it in sufficient quantity, after the smolt stage is passed, to nourish them. Therefore neither salmon nor their scales can grow in fresh water. It was further noticed that most scales taken from kelts—that is to say from salmon which, having spawned, have not yet returned to the sea—were broken and torn at the edges. From these facts Mr. Johnston argued that the sort of marks illustrated at C and D on the accompanying photographs (text-figs. 100 & 101) showed that the fish bearing them on their scales had entered fresh water and stopped growing there; that they had spawned and become shrunken after spawning, so that, from mechanical reasons, the scales being imbricated, *i.e.* overlapping each other like tiles on a roof, had become frayed at the edges; and, lastly, that on the salmon's return to the sea the new growth had started again evenly round the scale and thus left the mark. Spawning operations mean a winter at least spent in fresh water and, therefore, if the fish enters a river early in the year there will be fewer than the normal number of lines between the winter bands formed on each side of the spawning mark. If it comes in early in the spring there will be none in that year, and in the year following there will be fewer than usual on account of the fish taking some time after its return to the sea to make up lost condition before it starts again to increase in size. Of course, the later the salmon came into the river the more lines would have been formed behind the mark, and the later it returned to the sea the fewer would there be in front of it.

Besides the irregular arrangement of the lines on the scales when a fish has spawned, there is a thickening round what was the edge of the scales at the time the salmon left the sea, and this thickening is apparent both on the anterior and posterior parts of the scales if the edges have not become too much worn during the stay in fresh water. I account for it by supposing that the materials which go to form the scales are still being secreted in fresh water, and that as the skin

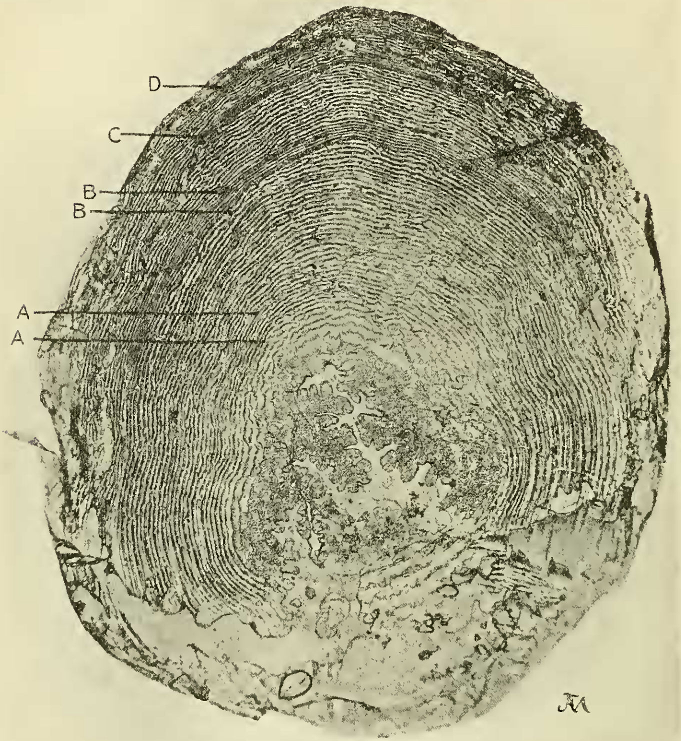
Text-fig. 100.



Scale of 33 lb. Salmon (*Salmo salar*) caught in the Tay in August 1903. This fish had spawned twice, and the marks are shown at C and D.

pockets have ceased to grow they can be deposited only on the scale edges already formed. The cells from which the concentric lines on the upper surface are evolved are already dead, except close to the periphery of the scale (Klaatsch, 'Zur Morphologie der Fischschuppen,' 1890, and Stuart Thompson, 'Journal of the Marine Biological Assoc.' vol. vii. no. 1, 1904). This in itself would account for the marginal thickening if the cells still remain active in fresh water and the scale cannot expand.

Text-fig. 101.



Scale of a 33½ lb. Salmon (*Salmo salar*) caught at Port Gordon, Aberdenshire, on August 19th, 1908. Previously marked as a kelt on the Deveron, March 23rd, 1908. This fish had also spawned in the previous year, and the two marks are shown at C and D. The original scale has been lost at the end of the first summer in the sea, and its position filled by a new scale without lines.

On both text-figs. 100 & 101 two spawning marks are to be seen, but the figures illustrate what I have just said as well as if they had but one mark. Scales which like these show two marks are far from common. The central part of text-fig. 101 is without lines, so that the parr scale does not show at all. This is because the original scale was lost by the fish towards the end of its first summer in the sea, and the place occupied by it in the skin pocket was filled by a new scale which, the line producing cells having died, is devoid of concentric lines. In both text-figs. 100 & 101 the first winter band formed in the sea is shown between the ends of the lines AA. The second winter band is between the lines BB. The first spawning mark in each case is at the end of the line marked C and the second spawning mark at D. Text-fig. 100 is a scale from a 33 lb. salmon caught in the Tay in August 1903. It can be seen, from the few widely spaced lines between the band BB and the spawning mark C, that when it first spawned it was a summer fish about 4½ years of age. After spawning the scale had become much worn, so much so that, except in front, not only the summer growth but the band BB had disappeared, and the new growth formed after the fish returned to the sea can easily be distinguished, its lines being again continuous round the scale. In text-fig. 101 the winter band of the 5th year had begun to form before the spawning mark C, so it was evidently a late autumn salmon. In text-fig. 100 the second spawning mark is indicated by the line D. The fish must have returned to the sea after the first spawning early in the year, and the lines between the two spawning marks show it to have come in to spawn the second time late in the summer of the same year. The following summer it was coming back to spawn a third time when it was captured. The thickening on the posterior part of this scale, due to both spawning periods, is clearly visible in the form of dark lines. In text-fig. 101 the second mark D, like the first mark C, denotes an autumn fish. It is not a very clear spawning mark, but I have chosen it for that very reason, because it is so like the mark on the scale of the Quinnat which I believe to have spawned (see text-fig. 95, p. 574) and because I have undoubted evidence that mark D on text-fig. 101 is a true spawning mark. The fish was caught as a kelt, weighing 22½ lbs., and marked by my own gamekeeper, Peter Bowie, at Netherdale on the River Deveron, on March 23rd, 1908. He put in its fin one of the Scottish Fishery Board labels numbered 3613 B. The scales then showed only the first spawning mark C. The fish was recaptured as a clean salmon, weighing 33½ lbs., in a bag-net at Port Gordon on the Aberdeenshire coast on August 19th, 1908, after only five months' interval. The mark D thus certainly represents the second spawning period during which my keeper caught and marked the fish.

Many other instances have occurred in which fish that have been marked with distinctive numbers as kelts have been caught again, and in every case they have proved the truth of Mr. Johnston's theory by showing a spawning mark on their scales. On the other hand, no fish that one knows from its age could not have spawned has ever been found to bear quite the same sort of mark, although various marks indicating sudden checks in feeding may appear.

I have entered somewhat fully into the above description of spawning marks, because I hope that now many scales of Pacific salmon will be examined upon the chance of finding one. Much can be done with an ordinary high-powered pocket-lens, and for close observation only a very low-powered microscope is either necessary or desirable. I find a $1\frac{1}{2}$-inch objective powerful enough for all purposes. One wants to be able to see as much as possible of the scale at the same moment.

Mr. Knut Dahl ('Age and Growth of Salmon and Trout in Norway,' London, 1912) has shown that the size of a fish at any period of its life may be deduced from its scales.

A fish does not change its scales. From the time they form they are retained through life unless removed accidentally. If a fish does by chance lose one it is replaced by another of the same size and shape but without the concentric lines—see text-fig. 101. It follows that as the fish grows, but remains covered by the same number of scales occupying the same relative positions, the scales must grow with the fish, and the growth of each scale be proportionate to the growth of the fish. If, then, the protected part of the scale be measured along its length from the centre to the anterior edge and again from the centre (by which I mean the nucleus) to, say, the first winter band, the lengths of the scale at these two points will be proportionate to the lengths of the fish at corresponding ages. An example will make this more clear. Suppose we have a salmon 75 cm. long and that one of its scales, when magnified, measures 55 mm. from the centre to the anterior edge, and 11 mm. from the centre to the point at which the rapid growth, consequent on migration to salt water, is seen to begin. Then as 55 is to 11 so is 75 cm. to the length of the fish when it entered the sea. The smolt was therefore 15 cm. (or just under 6 inches) long. Another scale from the same fish magnified to the same degree, might be only 45 mm. long, but then the other measure would be found to be 9, and the sum would work out just the same.

Dahl has proved his theory by measuring the scales of hundreds of salmon and trout from different rivers. He has always found that the actual average lengths of the fish in different rivers at various ages, agree almost exactly with the lengths calculated by him from the scales of the older fish.

I have been trying to apply this method of measurement to the scales of Pacific salmon, and I will give the results when I come to deal with each species separately. First, however, I must make some criticisms on what I have set out above as my understanding of the claims made by Dahl. I tried to check his theory on the scales of two salmon which had been marked as kelts and subsequently captured as clean salmon. Photographs of both of these scales form illustrations to Mr. Johnston's second paper on salmon scales in the 25th Annual Report of the Fishery Board for Scotland. The lengths, on the occasion of each capture, are given elsewhere in the 24th and 25th Reports, so it is known that the salmon marked No. 9194 was 27 inches long when taken as a kelt, and 31 inches long when recaptured. The other fish, marked 1180, was $26\frac{1}{4}$ inches long as a kelt and 36 inches long when recaptured. The measurements on the photographs of the scales from the centre to the anterior edge, and from the centre to the spawning mark are 130 and 116 for No. 9194, and 198 and 175 for No. 1180, the unit of measurement being $\frac{1}{64}$th inch. This would give the kelt measures as $27\frac{3}{4}$ inches and 32 inches respectively. The former measure is only $\frac{1}{2}$ inch wrong, but the latter is nearly 6 inches wrong, and shows either that the scale is abnormal or that Dahl's system of measurement is not applicable to a fish that has spawned.

Another criticism is that measurements from several different scales of the same fish seldom all agree exactly, and I have therefore come to the conclusion that it is very unsafe to rely on the measurement of one scale in estimating the size of the fish at various ages. The reason may be that it is not easy to recognize either the *exact* centre of growth, or the *exact* limits of the

Text-fig. 102.

Quinnat (*O. tschawytscha*). 25 lbs. 13th October, 1911. Shuswap, South Thomson River.

The black lines show the variations in the long axis of the scale.

various bands, but I do not think that the scales grow quite equally. Still the idea seems so well founded in theory, and to have worked out so exactly in practice on a large scale in Norway, that I believe I may consider myself justified in drawing conclusions from the average measurements of a considerable number of scales taken from the same fish, and whenever possible, I have measured 20 scales. A smaller number might suffice in the case of a true salmon, but the scales of the Pacific salmon are more difficult to read. As a rule, the limits of the bands are less clearly defined, and the change of growth, which I can only suppose to be due, as in the case of the true salmon, to the commencement of sea life, is more gradual and not so well marked. In addition to this, the long axis of the scale frequently shows more than one change of direction, the scale apparently being liable to get turned round in the skin-pocket. The accompanying photograph (text-fig. 102) will show my meaning. I have not measured such scales as these.

To come now to what is known, and to what I think I may claim to have found out about the various species of Pacific Salmon.

The Sockeye. (*Oncorhynchus nerka.*)

First I take the Sockeye, because it is the mainstay of the canning industry of the West. The number of Sockeyes canned on the Pacific coast in 1909 must have attained to the enormous total of about 50 millions. The exact weight was 214,980,448 lbs., or nearly 100,000 tons.

Text-fig. 103.

Sockeyes (*Oncorhynchus nerka*) running up Scotch Creek, a tributary of the Fraser River, British Columbia. (Photograph reproduced by kind permission of Mr. Frank Parry.)

The Sockeye is not much in evidence south of the Columbia River, in which it is known as the Blueback, but is plentiful from there the whole way north to Bering Sea. In Alaska it is known as the Red Salmon. The chief Sockeye stream is the Fraser River, which these fish ascend to spawn in countless myriads. The feeding-ground of the Sockeyes is somewhere far out in the Pacific, and the fish seem to cease feeding before they approach the coast, for even when caught in the sea near the coast their stomachs are invariably empty. This, however, may be from lack of means rather than from want of will. When one hears of a shoal of fish, seven miles broad and of unknown length, heading for the land through the Straits of San Juan, one can well imagine difficulties in the commissariat. Part only of this big shoal enters the Fraser River, the remainder moves on up the coast of British Columbia. The photograph (text-fig. 103), which I give by kind permission of Mr. Parry, late of Granite Creek Hatchery, shows a detachment on its way up Scotch Creek, a subtributary of the Fraser River, about 300 miles from the sea.

The big run of which I have been speaking strikes the south-west coast of Vancouver Island in July and August, coming from the north-west, but a few Sockeyes run as early as April. In the Fraser River itself the main run is in August, and some continue to come in until October. In the far north of Alaska the main run is as early as June, which goes some way towards showing that the feeding-grounds are in the north, unless a natural instinct to get spawning over before the winter sets in has determined the habits of the fish frequenting the most northerly rivers. In the Fraser district spawning begins in August, and may go on until November; spawning takes place only in streams running into or out of lakes. In this district, from which most of my information and all my specimens have come, several hatcheries have been established, which in 1910 liberated 134,639,200 Sockeyes in British Columbian waters. Besides these 4,544,825 were liberated from U.S. hatcheries in Puget Sound, and 257,021,790 in Alaska.

I am indebted to Mr. W. J. Sim, who was employed at Granite Creek for some years, for the information that the fry are liberated from the Canadian hatcheries as soon as the yolk-sac has been absorbed, at a period of the year which varies from January to April, according to the date of spawning. The main liberation is about the first week in February. In that district the fry may remain in the creek for two months or less; then they move into Shuswap Lake. The exodus from the lake takes place from June to September. The fry are supposed to be under one year old at the time of their exodus from Lake Shuswap, but no one really knows how long they may have remained in this, or in any other lake, and it is admitted by some observers that they may be in their second year. Dr. Greene, writing in the Bulletin of the U.S. Bureau of Fisheries, vol. xxix. 1909, on the Migration of Salmon in the Columbia River, and quoting Evermann, says the fry begin their seaward journey not sooner than September of their first, and not later than July of their second year. That means, I presume, that they leave the lakes when from nine to eighteen months old. But others, *e. g.* Rutter, Bulletin U.S. Bureau of Fisheries, vol. xxii. 1902, p. 102, say that they begin to descend the rivers as soon as they can swim, and reach the sea in about three months. Mr. Sim says he is certain that there are no fry in the rivers after September, and that they could not possibly avoid being swept down with the current as soon as they leave the lake.

The question as to the age at which the fry enter the sea is one which scale-readings should easily settle. So far, I have been

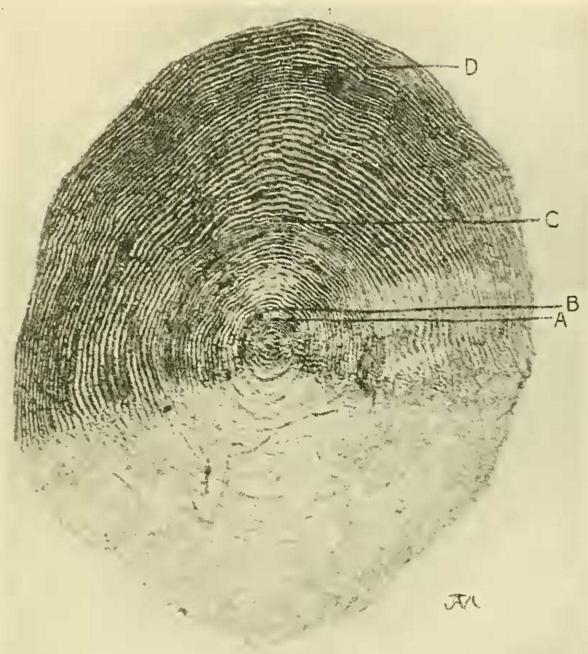
Text-fig. 104.

Scale of Sockeye (*O. nerka*), ♂, $3\frac{1}{4}$ lbs. Length $20\frac{3}{8}$ inches; girth $10\frac{1}{2}$ inches.

A=end of first year's growth. B=migration to sea.
C=end of second winter, D=end of third winter.

unsuccessful in my attempts to procure any specimens of fry of known ages for the purpose of seeing how their scales do actually grow, but I give some illustrations of Sockeye scales from full-grown fish (text-figs. 104–106). I have no doubt but that each one of these Sockeyes spent a year at least in fresh water, and the first of them probably not less than 15 months. I can conceive of no other way in which scales with centres similar to these could have been formed. They are the only Sockeye scales which I have from measured fish, but I have others from six fish of which I know only the weights, and a great many more from Sockeyes that unfortunately were neither weighed nor measured. All have similar centres.

Text-fig. 105.

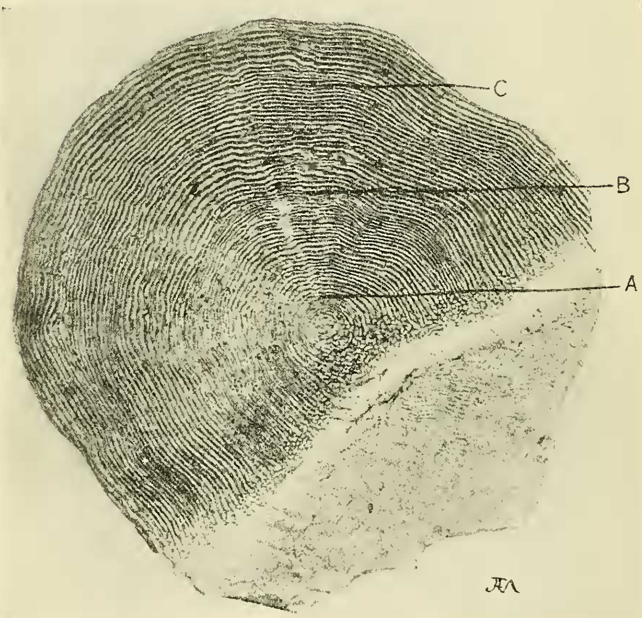


Scale of Sockeye (*O. nerka*) ♀. $5\frac{1}{2}$ lbs. Length $24\frac{1}{4}$ inches; girth $12\frac{1}{4}$ inches.

A=end of first winter. B=migration to sea.
C=end of second winter. D=end of third winter.

The Sockeye from which the scale, shown in text-fig. 104, was removed, was caught last August at New Westminster, near the mouth of the Fraser River. It weighed $3\frac{1}{4}$ lbs. and measured $20\frac{3}{8}$ inches in length and $10\frac{1}{2}$ inches in girth when captured. I have measured 20 scales from this fish, the average length of the enlarged images to which I applied the measure being 33 mm. from the centre to the anterior edge. The other average measurements to the points denoted by the lines drawn on the figure were 5 mm., 6·5 mm., 10 mm., and 20 mm., and the lengths of the fish at the various ages indicated work out as follows:—At the end of the first year $2\frac{3}{4}$ inches; when it entered the sea $3\frac{1}{2}$ inches, at the end of the second year 6 inches, at the end of the third year $12\frac{1}{3}$ inches, and when caught it was as stated $20\frac{3}{8}$ inches. The points indicated by the lines drawn on text-fig. 104 are calculated from the averages of the 20 scales, and they appear to coincide absolutely with the points I should have marked from examination of this scale alone.

Text-fig. 106.



Scale of Sockeye (*O. nerka*), ♂, 7 lbs.. $26\frac{1}{2}$ inches long; girth $14\frac{3}{4}$ inches.

A=migration to sea at end of 1st year. B=end of 2nd year. C=end of 3rd year.

The next scale, text-fig. 105, is from a Sockeye caught at the same place and time. In the illustration the parr or fingerling scale is not very clear, but the examination of 20 scales enables me to put the lengths of the fish at the various points and times indicated by the lines drawn on the picture as follows:—1st year $2\frac{1}{3}$ inches, entered the sea during the second year when 3 inches long, was already 9 inches long at the end of the 2nd year, $19\frac{1}{2}$ inches long at the end of the 3rd year, and, as was known,

$24\frac{1}{2}$ inches at the time of capture near the end of the fourth summer.

The scale of a Sockeye, also taken at New Westminster in August, is shown in text-fig. 106. In the case of this fish, the entry into the sea seems to have coincided with the end of the first year's growth. That is to say, it was some time during the winter 1909–10. The readings from 20 scales show it to have been then $2\frac{3}{4}$ inches long. At the end of its second year it was $11\frac{1}{4}$ inches long, at the end of its third year $21\frac{1}{4}$ inches, and when captured $26\frac{1}{2}$ inches.

The great difference in growth of the three fish in the second year is very noticeable, but it seems quite natural, and goes far to confirm the accuracy of my reading of the parr scale, when it is observed that the fish which appears to have spent the whole of its second year in the sea has grown most, and that the one which spent the longest part of it in fresh water has made the least progress.

It is further to be noticed that these fish all returned to spawn when of the same age, namely at the end of their fourth year. I have the scales of nine Sockeyes from the Fraser River. They varied in weight from $3\frac{1}{4}$ to $8\frac{1}{2}$ lbs., but all are in their fourth year. In British Columbia the Sockeyes weigh from 3 to 10 lbs. Fish up to 17 lbs. have been caught, but over 10 lbs. they are very rare. I therefore seem to have got specimens of all the average weights. That they are all of the same age may be an accident, but much more probably it is not, and if it is not an accident it is a fact of the utmost importance to the Fraser River District.

In the Fraser River the run of Sockeyes in every fourth year, the year after leap year, is almost six times as large as in any of the intervening periods of three years, and this has been the case as long as records go back. Whether the fourth years have shot ahead of the others, or whether all years were once equal to them will never be known, but most likely adverse breeding seasons in the intermediate years have gradually diminished the stock. If it proves upon further examination of scales that every Sockeye returns to breed in its fourth year in this district, it might well be centuries before the breeding stock, once diminished, increased to its original numbers. British Columbia has now only one season out of four up to what might be the mark; and, if I am right, the inference is obvious that the efforts of the hatcheries should be devoted chiefly to the collection of ova in the lean years even if they have to import them from other districts. In the springs of 1906 and 1910, the years following the last two big years, 100,479,000 and 105,312,500 Sockeyes were liberated from British Columbian hatcheries. In the intermediate years the numbers were only 36,965,900; 51,855,200; and 41,909,500. My contention is, that if it is humanly possible the numbers hatched out in the seasons following the lean years should be made even greater than after the fat years. Some people may say, "But how do we know that if we turn out fry in the Fraser

River or its tributaries, they will return there when they grow up?" The very fact that it is in that district alone that three years out of every four are lean years shows that the fish return to their own river. If it were not so, the shortage in these years would have gradually spread itself over a wider area. It seems all the more wonderful that it has not done so, when it is remembered that the big shoal which comes in in the summer is by no means solely composed of fish making for the Fraser. The facts further appear to show that not only do the fish return to the Fraser,

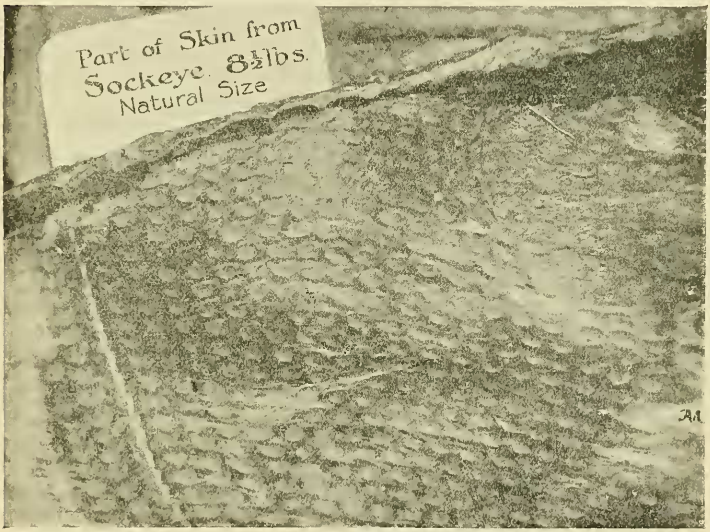
Text-fig. 107.

Scale of Sockeye (*O. nerka*) removed after spawning.

but to the very creek in which they were hatched, for how otherwise can one account for many of the creeks which are full of spawning fish in the big years being always absolutely untenanted in the years between them. Salmon marking in our own country has now shown almost conclusively that when the access to a river is unimpeded the salmon born in it invariably return to it. The fish that have been marked in one river and subsequently recaptured in another have all been from some comparatively small stream, or from some river with a bad mouth which they might well find difficulty in entering again when they wished to do so.

The value of hatcheries is a much-disputed point on which I will not express any opinion. For the moment I am content to assume that they are of some value on the Fraser, and that being so, to point out how they can best be utilized. But I will say that if the falling off in the catches which has been apparent since about 1900, when each year is compared with the fourth year before it, proves to be more than a mere temporary fluctuation, hatcheries alone will certainly not remedy the evil, and it will be necessary for a time at any rate to restrict the number of fish that are permitted to be caught.

Text-fig. 108.



Piece of skin taken from a Sockeye (*O. nerka*) after spawning.

I should mention that I have scales from Sockeyes in their fifth year, but they came from the State of Washington, not from the Fraser.

In text-fig. 107 is shown the scale of a Sockeye which weighed 6¼ lbs. and was caught at Morris Creek near Lake Shuswap, about 300 miles from the coast. So far as I can judge it is quite typical, and its interest is in showing, from the worn condition of its edge, that if a Sockeye ever returned to the sea after spawning and was caught again, a clear spawning mark should be apparent on its scales. The scales lie so far apart, and are so flexible, that unless one saw how much they may become worn one would hardly believe it possible.

It will, I think, be news to most of those employed on the hatcheries that the spawning Sockeye possesses scales at all. Last year when I asked for scales from a hatchery, I was told that it was well known that the Sockeyes absorbed all their scales as food in the course of their run up the river and never had any when they reached the spawning beds. I argued the point, and the hatchery people ultimately sent me the piece of skin shown in text-fig. 108 taken from a Sockeye that had spawned, to convince me that I was wrong. The scales were there, but are by no means so clear in reality as they are in the photograph. They are very deeply imbedded in the skin, and, in order to remove some of them for examination, it was necessary first to soak it well and then to pull and stretch it so as to open the skin-pockets. After that the scales were still invisible and adhered closely to the skin which formed the top of the pockets. It was possible, however, to remove them with a pair of forceps without much further difficulty. So even those who have handled spawning Sockeyes for years may be excused for thinking them to be without scales.—How many fishermen in this country know that eels are covered with scales?

The Quinnat (*Oncorhynchus tschawytscha*).

The known range of the Quinnat on the American Coast is from the Ventura River in California to Norton Sound, Alaska. It probably really extends into Arctic regions. The Quinnat is also known as the Chinook Salmon, the King Salmon, the Tyee, the Red or the White Spring Salmon, and the Black Salmon. The flesh is generally of a deep salmon-red colour, but in the south of Alaska and down to Puget Sound, sometimes as many as one-third of these fish have white flesh. Sometimes one half of the body is red and the other white, and sometimes the flesh is mottled. The white-fleshed fish are of little use. All the scales sent me and marked as from either Red or White Spring Salmon are from fish which have spent three winters, and a considerable part of the feeding season following the last winter, in the sea. Analogy from the true salmon would lead one to suppose that the white and mottled fleshed Quinnats might be fish that had spawned, but I can find no trace of a spawning mark on any of their scales. It has been suggested that the Red and White Spring Salmon are distinct varieties and that the specimens with mottled flesh are crosses, but upon this point I can offer no opinion. Differences in food might account for much, as in the case of the Brown Trout (*Salmo fario*).

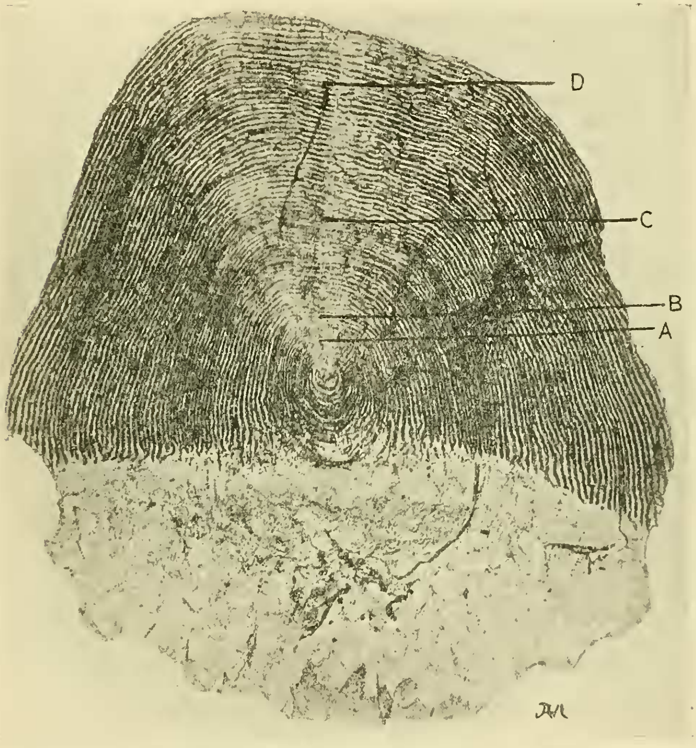
The name Black Salmon arises from the colour assumed by the Quinnat at spawning time.

In 1909 the weight of Quinnats canned on the Pacific Coast was 12,640,344 lbs.

As a rule Quinnats weigh from 18 to 30 lbs. in British Columbia, but much larger specimens are taken, and in Alaskan waters they have been caught over 100 lbs. in weight, and average 23 lbs. in some seasons.

Quinnats are very powerful swimmers and ascend fast-running streams in preference to others, making for the head waters, and sometimes running up for many hundreds of miles.

Text-fig. 109.



Scale of Quinnat (*Oncorhynchus tschawytscha*). 15 lbs. Length $31\frac{3}{4}$ inches; girth $19\frac{1}{2}$ inches. New Westminster, August 1912. (For references see text, p. 596.)

Most of the principal rivers have spring and autumn runs, and some of them a summer run also, so Quinnats may be said to run from January until October.

The scales I have examined show the running Quinnats to be in their fourth and fifth years, those over about 30 lbs. in weight being a year older than the others. Numbers of them are spawned in the hatcheries, from which it was estimated that 90,740,472 were liberated in 1910.

I have already shown photographs from scales of Quinnats which weighed $33\frac{1}{4}$ lbs. and $62\frac{1}{2}$ lbs. (see text-figs. 95 and 96, pp. 574 & 575) and I now append another (text-fig. 109) from a fish which weighed 15 lbs. The parr or fingerling stage of each scale shows that the fish spent a year (A) and the greater part of a second year (B) in fresh water.

I have examined scales from eighteen Quinnats varying in weight from 10 to $62\frac{1}{2}$ lbs., and all show about the same duration of the freshwater stage.

When the little fish enter the sea they seem to be already larger than the Sockeyes, and to measure from 4 to 6 inches in length. The lengths of the $62\frac{1}{2}$ lb. fish at various ages, deduced from the measurement of eleven scales, were as follows:—At the end of the first year $2\frac{3}{4}$ inches, when it entered the sea in its second year $4\frac{1}{4}$ inches, at the end of the second year $13\frac{1}{3}$ inches, at the end of the third year 25 inches, at the end of the fourth year 39 inches, and when captured it measured $50\frac{3}{4}$ inches. The scale illustrated (text-fig. 96) agrees exactly with these averages up to the end of the third year, but the position of the fourth winter band on it would show the fish to have been about 40 inches long at that time instead of 39 inches, if that scale alone were to be depended upon.

The lengths of the 15 lb. fish, as shown from 22 scales, were, at the end of its first year $3\frac{1}{2}$ inches, when it entered the sea $5\frac{1}{4}$ inches, at the end of its second year $13\frac{3}{4}$ inches, at the end of its third year 26 inches, and when captured it measured $31\frac{3}{4}$ inches. Text-fig. 109 shows the points from which the measurements were taken, the scale being exactly an average one.

The measurements of the $33\frac{1}{4}$ lb. fish, averaged from 16 scales, were, at one year $3\frac{1}{4}$ inches, when it entered the sea $4\frac{3}{4}$ inches, at the end of the second year $12\frac{1}{4}$ inches, at 3 years $21\frac{3}{4}$ inches, at 4 years 31 inches, and when captured $41\frac{1}{2}$ inches.

The above seem to be about the average lengths of Quinnats at the ages given. None of the twelve specimens I have measured depart far from them.*

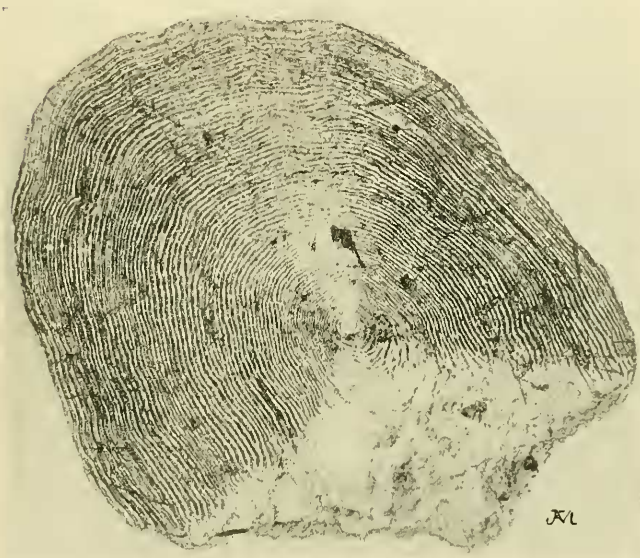
The Spawning Mark.

On the scale of the $33\frac{1}{4}$ lb. Quinnat (text-fig. 95, p. 574), a check in growth (*S*) may be observed beyond the fourth winter band (E). It is equally clear on every scale of this fish, and I think it must be a spawning mark. One might expect

* *Note*:—Since this paper was written I have ascertained that in the Natural History Museum, South Kensington, there are specimens of Quinnat parr, about 4 inches in length, which came from a lake near the head waters of the Fraser River. I have had the privelege of examining the scales of one of these specimens which measured about $4\frac{1}{4}$ inches. The first winter band is quite clear, and five lines formed in the second summer are apparent.

a better defined scar, but Quinnat scales are very thin and flexible, and besides are well protected by a great thickening of the outer skin at spawning time, so they may never become much worn at the edges. That they may not have become much worn up to the actual time of spawning is shown by text-fig. 110, a photograph of a scale removed from a 12 lb. Quinnat *after* it had spawned in the South Thomson River, about 300 miles from the sea. That scale not only sustained the wear from the shrinkage of the fish owing to lost condition between the time at which it left off feeding, which the lines following the last winter band

Text-fig. 110.

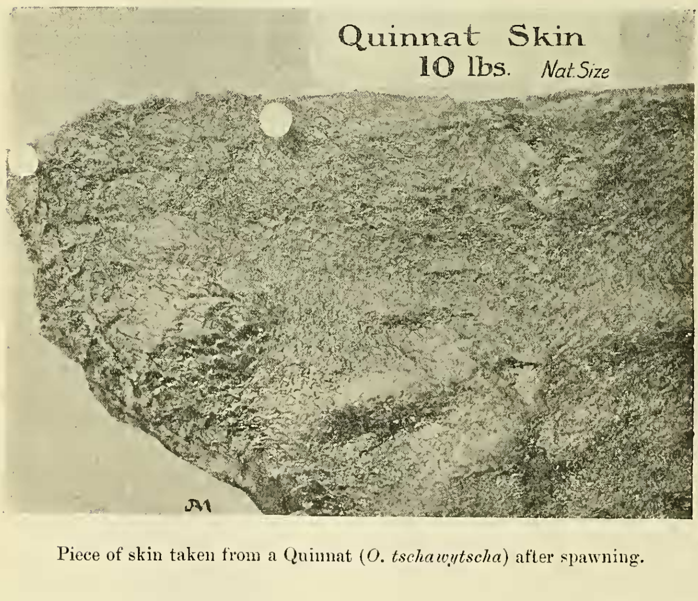


Scale of 12 lb. Quinnat (*O. tschawytscha*) from South Thomson River. Fish speared after spawning, 13th October, 1911.

show to have been quite early in the year, until it was speared for me under the supervision of Mr. John Brown of Celista, B.C., on the night of 13th October, 1911; but the skin was sent to me dried and folded, and I removed the scales from it myself. As this scale shows so little sign of wear at the edge, it seems to me quite conceivable that the mark *S* on text-fig. 95 is a spawning mark. If it is not, I am unable to suggest any other explanation of it.

Compare text-fig. 95 with text-fig. 109. These scales were taken from fish caught at the same place at the same time. There are more lines after the last winter ring on the former than on the latter, and that in spite of what is a very obvious check in growth. The check clearly lasted long enough for the edges of the scales to become somewhat worn, for the lines following it do not at all points exactly follow the contours of those immediately preceding them. This fish cannot in these circumstances have grown faster than its fellow, which was feeding all the time, and yet there are 20 lines as against 12. If, however, it spawned it added the twelve lines between the winter band and the scar in the early part of the year 1911, and the eight lines outside the scar in 1912. It would have spent the early part of 1911 in the sea, then come in to fresh water to spawn, and remained there after spawning for some little time. It would then have returned to the sea in poor condition and possibly not very early in 1912, so that by the time it had made up condition and started to grow again it would add but another 8 lines or so to its scales before the spawning instinct again induced it to seek fresh water, and thus brought it to the place of its capture.

Text-fig. 111.



Piece of skin taken from a Quinnat (*O. tschawytscha*) after spawning.

Compare this mark also with the outer spawning mark on text-fig. 101, and note how like they are.

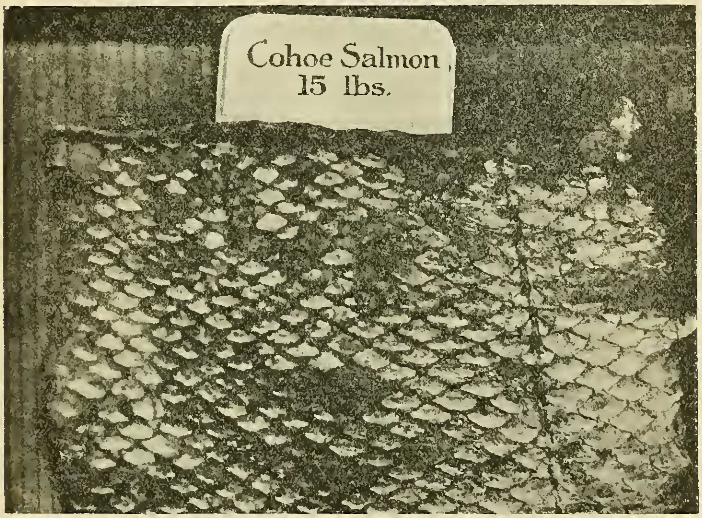
A Quinnat of about 30 lbs. is just the size on which I think a spawning mark is most likely to be found. The larger fish, like the $62\frac{1}{2}$ pounder, a scale of which is shown in text-fig. 96, have most probably attained their size on account of the feeding instinct being more pronounced than the sexual. Scale reading, so far as it has gone, has shown that our own very large salmon are all maiden fish.

Text-fig. 111 shows a piece of Quinnat skin taken from a fish that had lately spawned.

The Cohoe (*Oncorhynchus kisutch*).

The salmon with which I shall next deal is the Cohoe, also known as the Silver Salmon and the Fall Salmon. The photograph of its skin (text-fig. 112) shows that the scales overlap much more than those of either of the species already described. A spawning mark should therefore be better defined if one were to be found.

Text-fig. 112.



Piece of skin of the Cohoe (*Oncorhynchus kisutch*).

The Cohoe Salmon gets the name of "silver" salmon from its appearance when it first comes in from the sea. It is then a most brilliant silver with a greenish tint on the back. As spawning time approaches it becomes a dirty red. The Cohoe is found in almost all the Pacific Coast streams from Monterey Bay northwards. The run in the Fraser River is in September and October, but the Cohoes are on the coast from July to November. The weight of Cohoes canned in 1909 was 17,789,890 lbs., but large numbers, 1,152,452 lbs. in United States waters alone, were dealt with in other ways. The Cohoes in British Columbia weigh usually from 3 to 8 lbs., but larger specimens are by no means uncommon and may weigh as much as 30 lbs. More Cohoes would probably be canned if the run did not occur so late in the year, at a time when most of the canning stations are closed for the winter.

The number liberated from the hatcheries in 1910 was 50,424,386, but in some years the numbers have been much greater.

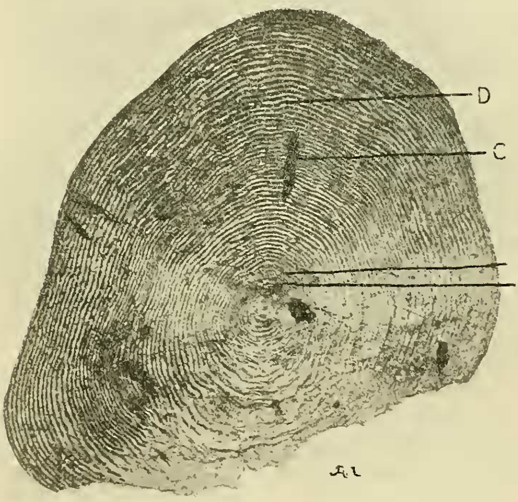
Text-fig. 113.

Scale of Cohoe (*O. kisutch*), ♀. 5 lbs. 6 oz. 17th November, 1911.

I find the scales of the Cohoes the most difficult of all to read. I have specimens of scales from eighteen fish from Puget Sound and from Shuswap, on the Fraser River. These fish varied in weight from 3 to 18 lbs. What strikes one as most curious is that, with the possible exception of one fish of 5 lbs. 6 oz. (text-fig. 113) in which a few close lines between B and C, which I think due to a slight check in feeding, may really be the second winter band, their scales show them all to have been of the same age, namely nearing the end of their fourth year.

I am satisfied that the Cohoes spend the whole of their first year in fresh water. At the end of it they measure, according to their scales, from $2\frac{1}{2}$ to 3 inches. One rapid grower, which weighed 15 lbs. near the end of its fourth year, measured as much as 4 inches at the time of migration. The growth in the second year is very difficult to make out. I feel convinced that the greater part of it (I mean as to time) has taken place in fresh water in nearly every instance, and in no instance am I quite convinced that the whole of it did not do so. If the whole of the second year's growth took place in fresh water, the fish are a year older than I have stated above. In all cases (I speak, of course, only of the fish I have examined) the first entry into the sea appears to have taken place between 18 months and 2 years after hatching. Further certainty is added to this statement by the measurements of the scales, which show the second year's growth to have been comparatively small. In three instances in which, from the arrangement of the rings, I think the fingerlings entered the sea when about 18 months old, the little fish were three times as long at the end of their second year as at the end of their first. None of the others even quite doubled their length. That is what one would expect at that stage from fresh-water feeding, but not from sea food. In the third year growth is very rapid, and hardly diminishes even as winter comes on.

Text-fig. 114.

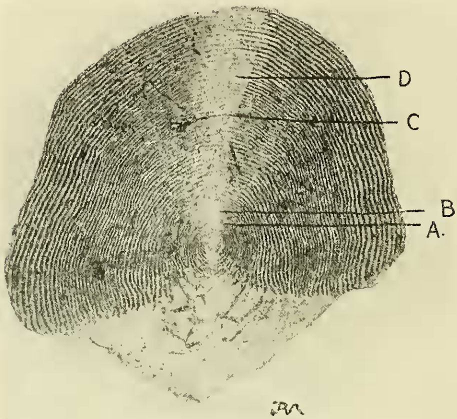


Scale of Cohoe (*O. kisutch*), ♂. 14 lbs. Puget Sound, 18th October, 1911.

Text-figs. 114 and 115 are typical Cohoe scales.

All the scales from Puget Sound are from fish captured on 18th October, 1911, and all show at their edges the lines coming close together to form the next winter band, see text-fig. 114. A similar formation may be noted on text-fig. 113, which reached its spawning ground a month later. But compare these scales with text-fig. 115. This fish was forwarded to me from Toronto on October 17th, so that it must have been procured at Lake Shuswap some days earlier.

Text-fig. 115.



Scale of Cohoe (*O. kisutch*), ♀. $3\frac{1}{4}$ lbs. Shuswap Lake. Weighed after spawning.

According to Dr. Greene (Migration of Salmon in Columbia River, Bulletin of U.S. Bureau of Fisheries, vol. xxix. 1909), a Silver Salmon travels about 7 miles *per diem*. This fish, then, to reach Shuswap by, say, October 12th, must have ceased feeding in the sea not later than 23rd August. It will be noticed that the outer lines of the scale are still widely spaced, showing that summer feeding and growth were still in progress up to the time at which the fish left the sea for the river.

The Humpback Salmon (*Oncorhynchus gorbuscha*).

I have but little to say at present about the Humpback, the Dog Salmon, and the Steelhead Trout.

The Humpback has flesh of a pale pink colour. It was not used for canning purposes until quite lately, but now there is a good trade in it with China and Japan, where it is much esteemed. The Chinese, not being accustomed to red-fleshed fish, were very shy of the canned Quinnats and Sockeyes when I was in China in 1893, and this may account for their partiality to the Humpback.

The total weight of Humpbacks canned on the Pacific Coast in 1909 was 100,326,144 lbs., and over another 3,000,000 lbs. weight was used in other ways.

Humpbacks were first dealt with in the hatcheries in 1904, and since then have been turned out from them intermittently, but never in very large numbers, comparatively speaking.

They take their name from a peculiar hump which appears behind the heads of the males at spawning time. They are from 3 to 11 lbs. in weight, and have very small scales.

The main run is in Alaska. South of Puget Sound the Humpback is almost unknown. In the Fraser River the runs in the big Sockeye years and in the years next but one after them are much larger than in the other years. The fish, however,

Text-fig. 116.

Scale of Humpback Salmon (*O. gorbuscha*), from Puget Sound.
(For reference see text, p. 604.)

seem to come in at various ages, so this state of affairs will probably gradually right itself again if the netting is not too severe. I am judging from possibly but a few specimens. A large number of Humpback scales have been sent me, but, unfortunately, with no further information than that they were taken from Humpbacks in Puget Sound on their way to the Fraser River. I append a photograph (text-fig. 116) of one of these scales. The centre is only moderately well defined, but in all the others it is even less clear, so that I have not been able to form any definite opinion as to the time spent in fresh water. This scale shows clearly one winter band formed in the sea (AA). I presume that it represents the growth of the second winter. All the scales show a similar band, and many of them another evidently formed a year later.

I can give no measurements as I do not know the length, or even the weight, of any of the fish when caught.

The Dog Salmon (*Oncorhynchus keta*).

The Dog Salmon frequents the Pacific Coast all the way from San Francisco to the Arctic Circle, but is most plentiful between Puget Sound and South-East Alaska. This fish is also called the Chum Salmon, and is known in Japan as Sake, and in Siberia as Kita.

I have not before referred to the prevalence of any of the species on the other side of the Pacific, and only do so now because the Dog Salmon has long been a staple food of Japan, and it is because this fish is white-fleshed, or almost white, that the red colour of the other varieties has caused them to be viewed with suspicion when exported to the East. This fact was ascertained by me when I was in China and Japan in 1893.

The Dog Salmon gets that name from the distorted appearance of the mouth of the males at spawning time. They then look not unlike snarling dogs. The average weight of the Dog Salmon is about 8 lbs. In British Columbia it is higher, from 10 to 12 lbs. 16 lbs. would be about the maximum weight.

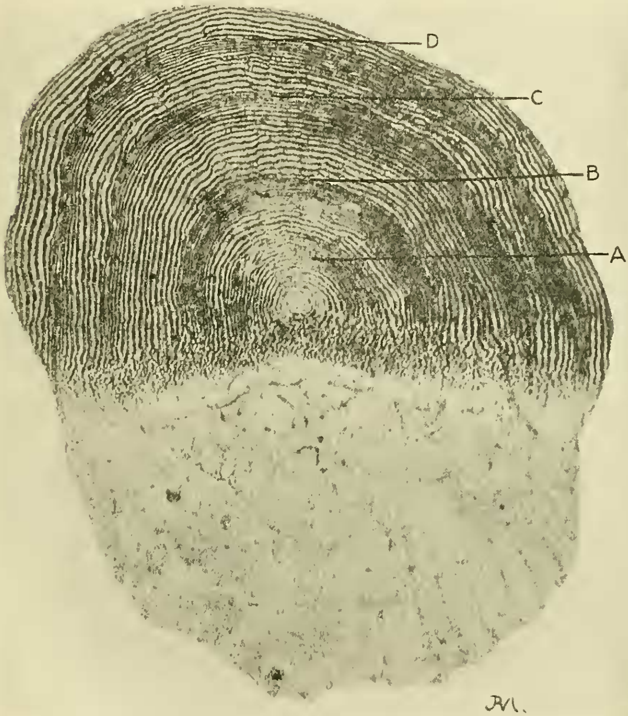
The weight canned in 1909 was 25,660.845 lbs., and over 4,000,000 lbs. weight was otherwise dealt with for export.

It is only in Washington State that these fish have been spawned in the hatcheries. There an average of about 7,000,000 fry have been turned out in recent years beginning with the year 1900.

As a general rule the Dog Salmon comes in late in the year, September to November. But in Alaska the run begins in June, and in the Fraser River in the middle of August.

In British Columbia they spawn close to the sea. This I had gathered from the appearance of the scales before I found out that it was known to be the case. I have received scales from two specimens weighing $11\frac{1}{2}$ and 12 lbs. respectively, both caught in Puget Sound on their way to the Fraser River. They show no indication of fresh water feeding at all. The fry evidently descend to the sea as soon as hatched out. The measurements of 10 scales of the $11\frac{1}{2}$ lbs. fish, one of which is shown in text-fig. 117, enable me to give the rate of growth as follows:—At the end of the first year $7\frac{1}{4}$ inches, at two years 13 inches, at three years 22 inches, at four years $27\frac{1}{2}$ inches, and when caught in its fifth year it measured 31 inches. Its capture was evidently an early one, as the summer growth is only just complete. Unfortunately I have not got the date. The 12 lbs. fish was caught at the same time and place. It was shorter, $30\frac{3}{4}$ inches, but thicker, 17 inches. Its length at the end of each winter was $5\frac{1}{4}$, 11, $20\frac{1}{2}$, and $26\frac{1}{2}$ inches. From a smaller beginning it was steadily overtaking the other fish in length, and had already done so in weight when caught.

Text-fig. 117.



Scale of Dog Salmon (*Oncorhynchus keta*). ♀. $11\frac{1}{2}$ lbs.
Length 31 inches; girth $16\frac{3}{4}$ inches.

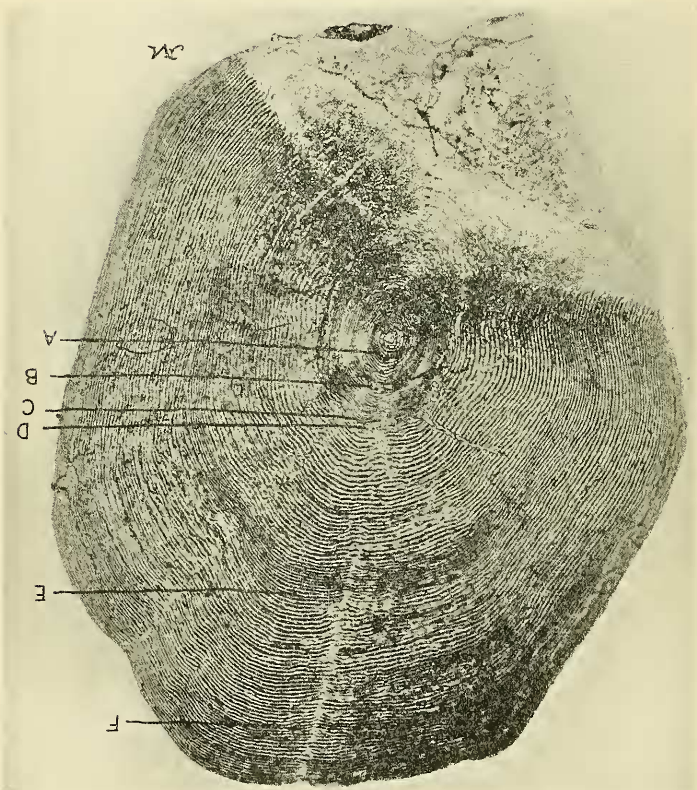
The Steelhead Trout (*Salmo gairdneri*).

The last of the Pacific Coast salmon with which I am dealing is the Steelhead, which is there called a trout, but is the only Pacific member of the sub-genus *Salmo*, to which the true salmon belongs. It is believed to be a migratory form of the Rainbow

Trout. The flesh is pale-coloured, and is not much used for canning.

The Steelhead is found from Carmel River, California, northwards to Central Alaska. In California it may be fished for only with hook and line. In 1909 4,229,704 lbs. weight was canned and 1,960,000 lbs. weight was otherwise used in the United States fisheries, without counting those frozen or salted in British Columbia.

Text-fig. 118.



Scale of Steelhead Trout (*Salmo gairdneri*), ♂. $12\frac{3}{4}$ lbs. Length 33 inches; girth $16\frac{1}{2}$ inches. New Westminster. Autumn, 1912. (For references see text, p. 607.)

In 1910 there were liberated by the U.S. hatcheries 12,023,646, but none was turned out in Canada.

The spawning season is in the spring, but Steelheads are to be found in fresh water at most seasons of the year. They weigh, on an average, at different places from 8 to 15 lbs., with a maximum of about 45 lbs.

The scales, of which I have specimens from several fish, but from only two that had been weighed and measured, show that life in fresh water before the first migration to the sea may be of considerable duration. In this species, as in the case of our own salmon, no doubt is possible as to the limits of the part of the scale formed in fresh water. From examination of a large number of scales from my two measured fish, I judge them to be about 7 inches long when they enter the sea. As spawning takes place in the spring, the number of lines on the scale at the end of the first winter is naturally very small. The scale illustrated in text-fig. 118 shows five up to the point A, and that seems the usual number, but the first band is not always visible on all the scales, which is not to be wondered at seeing how minute they are, $\frac{1}{40}$ inch long at the most, at that time.

A second winter in fresh water is shown in text-fig. 118 by the band B, and a third by the band C. Outside of it are two or three more lines added to the parr scale in the fish's fourth year, before it entered the sea. All the Steelhead scales which I possess show similar lines and bands, so I suppose one may take it that these fish remain in fresh water until well on in their fourth spring, counting that in which they were spawned as one. They would then be just three years old.

When they get to the sea they grow very rapidly. The first band completed in the sea within a year of migration shows my two measured fish to have been then already from $19\frac{1}{2}$ to $20\frac{1}{2}$ inches long (see text-fig. 118, E), and the second winter band shows a length of from 29 to $30\frac{1}{2}$ inches (text-fig. 118, F), but I am not sure that I have identified this band correctly on the scale illustrated. These two fish were both caught near the mouth of the Fraser River in the autumn of 1912, when they measured $31\frac{3}{4}$ and 33 inches respectively and weighed $12\frac{3}{4}$ and 13 lbs., the shorter and thicker fish being a female. They had then done a considerable amount of feeding in their sixth year.

This completes for the present my review of the salmon of the Pacific Coast of North America.

It must always be borne in mind that my observations have been made on the scales of fish from the Fraser River district alone, and that readings from the scales of salmon caught elsewhere might show considerable differences. Some divergence is almost certain in the duration of freshwater life, for observations of the scales of the true salmon (*Salmo salar*) have shown that the further north one goes the longer does the young salmon remain in fresh water, and it is not at all unlikely that the Pacific salmon are influenced in the same way by climatic conditions.

The strongest argument which I have heard in favour of the prevailing idea that Pacific salmon migrate to the sea as soon as they can swim, is that many of the rivers which they frequent are small, and, at times, are either dried up or frozen hard. This argument was put before me by a gentleman who is largely interested in the Pacific Coast fisheries and generally recognized as an authority thereon. It therefore seems to demand an answer. My answer is that I have examined only the scales of fish hatched in the large watershed of the Fraser River, and that possibly the fry of the Pacific salmon can adapt themselves to varying conditions. It is known that our own salmon, which generally migrate to the sea at two years of age, may enter it at one year without hurt, or may remain in fresh water for three, four, or even five years where the circumstances, as in Norway, make it desirable for them to do so.

But, even supposing that they can adapt themselves to a certain extent, I fail to see how any salmon can perpetuate its species in a river which is frozen absolutely solid in winter, or which is bone-dry in summer. In fact, I believe that the fish that run into small rivers where such conditions prevail have not been hatched in them at all, but are really natives of one or other of the large river systems, and that, when they get into one of these small rivers, they become at once of no further use to their own species, and might as well all be promptly utilized as food for the good of ours.

For a fact which supports this belief I have only to refer to what Mr. W. L. Calderwood says in a communication to the 'Salmon and Trout Magazine' for December 1912, page 24. He there describes Capt. Callbreath's hatchery in Alaska. I am not now concerned with the hatchery itself, but with the fact that it is on a river, the Jadeska, only half a mile long, which runs out of a small lake. A dam has been thrown across the river, only 100 yards from the mouth, so as to intercept all fish, and enable the operators to select the Sockeyes and refuse the other salmon. In addition to this dam a fence of racks has been erected having at one place a trap. Here the Sockeyes have been taken out and lifted over the dam, if not required for the hatchery, while the other species have been left below. This selection has gone on for eighteen years, and still continues, although the Sockeye hatchery was a failure and hatching operations were discontinued in 1906. Mr. Calderwood says :—"It is an interesting point that, although the natural and artificial propagation of the Humpback and Dog Salmon were entirely discouraged, the number of these fish continued apparently undiminished." He adds, and this is my point, "The moral may be that the fish in this river, like the fish in other small rivers, are largely drawn from other sources." But, in this case, as none but Sockeyes have been admitted to breed, it would seem proper to substitute the word "entirely" for the word "largely," and I submit that what applies to one small river may equally well apply to them all.

If the perusal of what I have written induces others to pursue this fascinating study of scales upon the lines I have suggested, my work will have served its chief purpose.

That the study is a most important one cannot be denied. The salmon fisheries of the Pacific Coast are a source of vast wealth to the countries so fortunate as to share in them. But that source of wealth, like our own salmon fisheries, already shows signs of having been too lavishly drawn upon. It is easy to kill the goose that lays the golden egg. By legislation much may be done to prolong its life, but legislation can effect its purpose only if based upon thorough knowledge. In this country, if salmon scales had been studied before the Acts which regulate our fisheries had been passed, these Acts would have been very different from what they are. The study of scales has so revolutionized our knowledge that, of the eleven facts in the life of the salmon, mentioned by Mr. Cholmondeley Pennell in 1886 as *absolutely* proved, one, the most important, has now been shown to be absolutely wrong, and two others, hardly less important, require much modification.

I have not made myself familiar with the various fishery laws and regulations of the Pacific Coast, but I know that many experts think them insufficient. If the regulations as to netting are to be made more stringent, let it be done with as complete knowledge of the various salmon as possible ; and in order that that knowledge may be obtained let their scales be systematically studied. For months, or years, the fish are hidden from our eyes, but from their scales we can fill in the gaps while they are out of view, for it has been well said that every salmon carries a record of its life on each of its scales. Whether I have read the records written on the scales of the Fraser River salmon correctly or not, I can at least claim to have proved that the records are there.

In conclusion, I have to thank Mr. W. J. Sim of Northville, Kings Co., Nova Scotia, for much valuable information, and for having procured me numerous specimens through his friends Mr. Frank Parry, now also of Northville and formerly of Granite Creek, Mr. J. Brown of Celista, B.C., and Mr. Josephson of Bellingham, Washington, U.S.A., and Mr. J. Kirkpatrick of Vancouver. The various statistics I have given have been compiled mainly from "The Salmon Fisheries of the Pacific Coast," by J. N. Cobb, Bureau of Fisheries, Document 751, Washington, 1911, and partly also from the Report of the Commission of Conservation on "Lands, Fisheries and Game, and Minerals," Ottawa, 1911.

The following table may prove of interest :—

	Sockeye, *O. nerka.*	Quinnat, *O. tschawytscha.*	Cohoe, *O. kisutch.*	Humpback, *O. gorbuscha.*	Dog Salmon, *O. keta.*	Steelhead Trout, *S. gairdneri.*
CHARACTERISTICS. *Note.*—This is a copy of the table published by Mr. G. A. Boulenger, F.R.S., in 'Country Life' for April 23rd, 1910. Number of gill-rakers on the anterior arch ...	32–40	20–28	20–25	28–36	20–25	
Number of well-developed rays in anal fin.	14–15	15–18	12–14	15–16	13–14	10–12
Number of scales on lateral line	125–135	140–155	125–135	150–170	135–145	
Number of lines of scales between lateral line and dorsal fin	20	25	25	30	25	
Number of pounds canned, pickled, frozen, or salted on the Pacific Coast in 1909, in millions of pounds—nearest million	215	13	19	103	30	6
Number of fish caught in 1909, calculated from total weight as given above, and general average weight in millions, after allowing one-fifth for waste	54	$\frac{3}{4}$	5	31	5	$\frac{3}{5}$
Number of fish liberated from the hatcheries in 1910 in millions—nearest million	316	91	50	2	7	12
Average weight of fish, as caught, in pounds	3–10	18–30	3–8	4	8–12	8–15
Maximum weight attained, in pounds, about	17	100	30	11	16	45
Approximate time spent in fresh water before migration to the sea, in Fraser River district, in months	12–15	18	18–24	?	3 or less	36
Approximate length at time of migration to the sea, in Fraser River district, in inches	$3–3\frac{1}{2}$	$4–5\frac{1}{2}$	$2\frac{1}{2}–5$	?	$1\frac{1}{2}$ or less	7
Age at time of return to fresh water, in Fraser River district, in years; as shown by my specimens	$3\frac{3}{4}$	$3\frac{3}{4}–4\frac{3}{4}$	$3\frac{3}{4}$	$2\frac{3}{4}–3\frac{3}{4}$	$4\frac{3}{4}$	$5\frac{1}{2}$